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G.L. Crouch

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Glenn L. Crouch

*ABSTRACT—Commercial clearcutting of mature quaking aspen (*Populus tremuloides*) on blocks ranging from 3 to 17 acres resulted in 30,000 sprouts per acre and 90-percent stocking of half-milacre plots after one growing season. Six years later, sprouts averaged 7,000 per acre, stocking was 76 percent, and mean height of the tallest stem was 8.1 feet. Although these numbers were adequate for restocking, the poor condition of most sprouts, resulting from cattle trampling and snow breakage, strongly threatens the successful replacement of sawlog-quality growing stock.*

Aspen occupies several million acres in the central Rocky Mountains (Green and Setzer 1974). About 4 million acres are in pure stands and suitable for commercial uses; other stands presently have little economic value but provide important wildlife habitat, forage and shade for livestock, and scenic values. Most of this aspen is in mature and overmature age classes.

Current management programs are designed to regenerate old-growth stands to provide variety in age and size classes, and to perpetuate the species where it is being replaced by other vegetation.

Aspen of sufficient size and soundness for wood products occurs throughout the central Rockies, but demand is currently low in most areas (Wengert 1976). Commercial value, however, will almost certainly increase, and forest managers must learn now how to harvest aspen with maximum benefits and minimum adverse effects on all resources, including wildlife.

One of the few relatively stable markets for aspen is in southwestern Colorado, where the San Juan National Forest has sold aspen stumpage regularly for more than 30 years. A sale starting in the early 1970s, of about 7 million board feet, has resulted in more than 60 clearcut blocks ranging in size from 2 to 20 acres. The study reported here evaluated response of aspen regeneration to the clearcutting.

Study Area

The study was conducted on the West Stoner Aspen Sale Area, about 25 miles northeast of Dolores, Colorado, on the San Juan National Forest. Elevations range form 9,000 to 9,500 feet and topography on the study area was gentle. The site was occupied by a nearly continuous, almost pure stand of mature to overmature aspen made up of many various-sized clones (*fig. 1*). The largest trees were greater than 20 inches in d.b.h. and up to 90 feet in height. The understory contained scattered snowberry (*Symphoricarpos oreophilus*) and a nearly complete herbaceous cover. The vegetation mostly

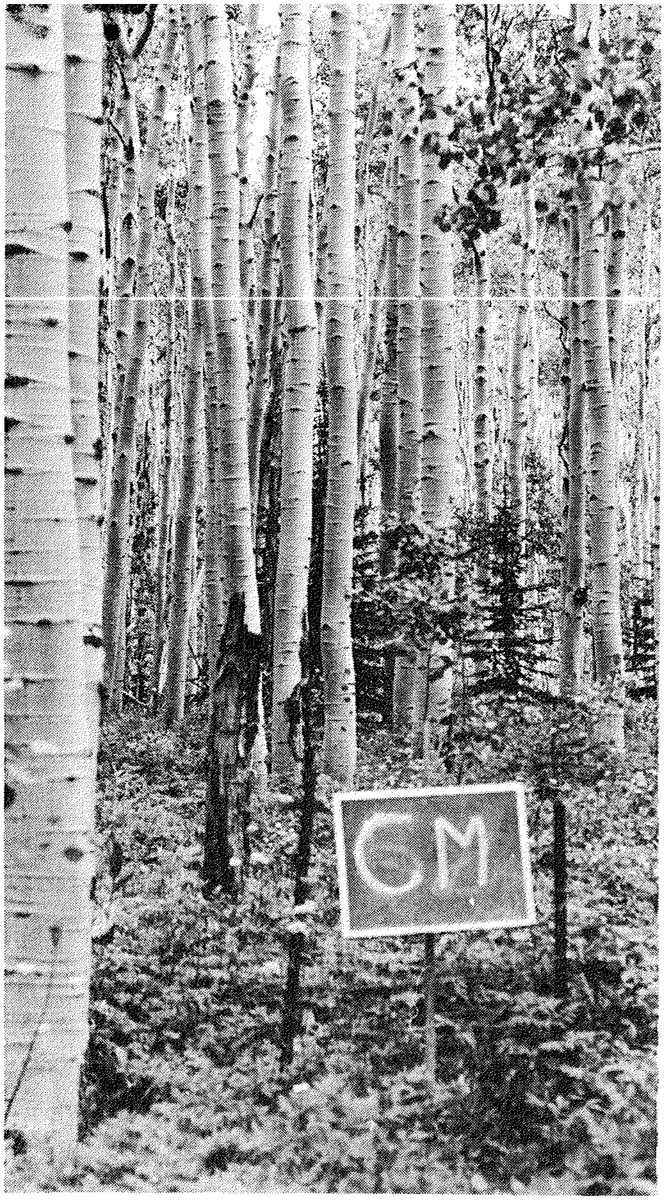

Figure 1. Uncut stand of aspen.

resembled the *Populus tremuloides/Symphoricarpos oreophilus* and *P. tremuloides/Thalictrum fendleri* habitat types described by Hoffman and Alexander (1980) some 200 miles northeastward, on the Routt National Forest. According to Dolores Ranger District records, about 600 acres or 25 percent of the stand was clearcut in addition to that cleared for roads.

Stoner Mesa, the study area location, provided late Erxleben), and seasonal habitat for other game and nongame birds and mammals that typically utilize such sites. Cattle also grazed there from mid-June to mid-October each year.

Methods

Data were collected from 18 blocks distributed over about 60 percent of the sale area. On 15 blocks, all trees greater than 1 inch in d.b.h. had been clearcut during the dormant season, with merchantable logs removed and slash scattered. Among these, three blocks were selected from each year of logging and slash treatment, from winter 1974 through winter 1978. Within each year class, one block was selected from each of the following size classes: 3–7, 8–12, and 13–17 acres. All blocks were rectangular. In addition, one block corresponding to each size class was established in uncut aspen as a control. These control blocks were isolated from cut blocks by at least 200 feet. The 15 clearcut blocks plus 3 controls made up the sampling sites.

Two sampling lines, approximately equidistant from the block edges and from each other, were established across the long axis of each block.

Overstory data were obtained from 2-milacre circular plots spaced 55 feet apart along the sampling lines in each control block. Numbers, diameters, and heights of all trees 1 inch in d.b.h. or larger were recorded, and increment cores were taken to determine the ages of sample trees. In addition, aspen sprouts in each plot were counted and their heights were measured. Canopy intercept was recorded at plot centers by use of a point-sampling device.

Information on regeneration was obtained from half-milacre plots similarly established along the sampling lines in the clearcut blocks and concentric with the 2-milacre plots on the uncut controls.

Data were collected in September 1979, and sprouts were recounted in September 1981 on the fourth- and fifth-year blocks, providing information from a seven-year posttreatment period. Data were subjected to analyses of variance and means were separated according to Tukey (Snedecor 1961) as appropriate. Confidence intervals $[\bar{X} \pm t_{0.05} (S\bar{X})]$ were used to indicate reliability of these mean differences.

Marginal Restocking of Crop Trees

Overstory aspen on uncut blocks averaged 198 square feet of basal area distributed on 650 stems per acre (*table 1*). About 60 percent of the trees and 90 percent

Table 1. Characteristics of aspen trees on uncut blocks on Stoner Mesa, southwestern Colorado, 1979.[1]

	DIAMETER CLASS (INCHES)				
Characteristic	1.0–1.9	2.0–5.4	5.5–10.4	10.5–15.4	All trees
Trees per acre					
Number	109 ± 61	158 ± 73	275 ± 93	108 ± 54	650 ± 114
Percent with decay	63	67	29	38	39
Stocking (percent)[2]	13 ± 11	27 ± 21	37 ± 7	25 ± 11	71 ± 19
Age (years)	22 ± 3	67 ± 10	84 ± 10	122 ± 10	80 ± 11
Height (feet)	13 ± 2	30 ± 5	51 ± 2	69 ± 7	42 ± 5
D.b.h. (inches)	1.3 ± 0.2	3.9 ± 0.5	7.7 ± 0.5	12.5 ± 1.4	6.5 ± 0.9
Basal area (square feet per acre)	1.1 ± 0.9	14.3 ± 6.8	70.0 ± 29.1	112.4 ± 53.8	197.8 ± 59.8
Percent of canopy cover					85 ± 5
Sprouts per acre					1,000 ± 249

[1] Confidence intervals = $\bar{X} \pm t_{0.05} (S\bar{X})$.
[2] Circular 2-milacre plots containing one or more trees.

Figure 2. Large clearcut block in the first growing season after logging


Figure 4. Five-foot tall aspen showing effects of leader breakage.

of the basal area were in the merchantable size classes (≥ 5.5 inches d.b.h.). Site index was estimated to average 60, according to index age 80 curves published by Jones (1967). Although dominants averaged more than 120 years in age, the stands sampled were virtually intact. They contained few fallen trees and only 17 standing dead trees per acre.

Stems under 5.5 inches in diameter contained considerably more decay than larger trees, an indication that this component would not provide commercially acceptable advanced regeneration when the older trees died (*table 1*). In addition, most of these trees were deformed and had sparse crowns. Existing sprouts averaged 1,000 ± 249 per acre, but most were also misshapen and in generally poor condition.

Numbers of sprouts on first-year clearcuts averaged 31,063 ± 6,400 per acre (*fig. 2, table 2*). This number was 44 percent greater than that found on a study area on the Routt National Forest (Crouch 1981), but much lower than the numbers counted in Utah by Baker (1925), Sampson (1919), or Schier and Smith (1979). Stocking in individual half-milacre plots ranged from 0 to 52 sprouts per plot, and 93 percent of the sample plots was occupied by one or more sprouts after the second growing season. Size class of clearcut had no significant effect on any measured attribute.

Virtually all of the sprouts produced in the first seven years were present in the first or second season. Numbers declined rapidly during the first five years after logging (*fig. 3, table 2*.) After seven years, blocks contained 7,210 ± 1,732 sprouts per acre, a loss of 77 percent, and stocking had declined to 76 percent. More important, it was estimated that only 35 percent of the oldest plots were occupied by at least one crop tree, because many of the sprouts in the older blocks were in poor condition—broken or scarred, or bushy, with no well-defined main stems (*fig. 4*).

Heights of dominant sprouts averaged 8.1 ± 1.2 feet in plots on seventh-year blocks. Height growth was similar to that reported by Sampson (1919) in Utah and on the Routt study area by Crouch (1981), better than that reported by Baker (1925), but poorer than that found by Jones (1975) in Arizona.

Many sprouts in the older blocks were decayed or had prominent stem discloration that appeared to precede decay (*table 2*). Most of these also had basal lesions or callused basal injuries. Correlation between discoloration and basal injury was high (r = 0.99), although not one-to-one.

Most Damage from Snow

Two major factors other than inherent characteristics of the species appear to have contributed to the decline in numbers and quality of sprouts. Trampling damage by cattle has been reported elsewhere (Smith et al. 1972). Cattle also contributed to the basal injuries observed on Stoner Mesa. Although allotment-wide stocking rates were relatively low, the tendency of cattle

Table 2. Characteristics of aspen sprouts on uncut and clearcut blocks on Stoner Mesa, southwestern Colorado.[1]

		Years since clearcutting						
Characteristic	Uncut	1	2	3	4	5	6	7
Number per acre								
Total	1,000e	31,063a	30,027a	22,373b	14,640c	9,920d	8,380d	7,210d
Current year	0c	30,920a	6,260b	640c	160c	80c	10c	0c
Basally injured (percent)	33b	0f	1f	12e	19d	26c	28c	40a
Discolored or decayed (percent)	47b	0f	1f	17e	27d	36c	39c	57a
Stocking (percent)[2]								
Total	27d	91a	93a	89ab	87abc	79bc	76c	76c
Potential crop trees	17e	91a	93a	78b	59c	47cd	40d	35d
Heights (feet)[3]	1.7f	1.9f	3.1e	4.2d	4.7d	5.8c	6.7b	8.1a
Browsed (percent)	5a	8a	2a	5a	4a	2a	1a	1a

[1] Means within each characteristic followed by the same letter are not significantly different at $P = 0.05$.
[2] Circular half-milacre plots containing one or more sprouts.
[3] Height of the tallest sprout in each sampling plot.

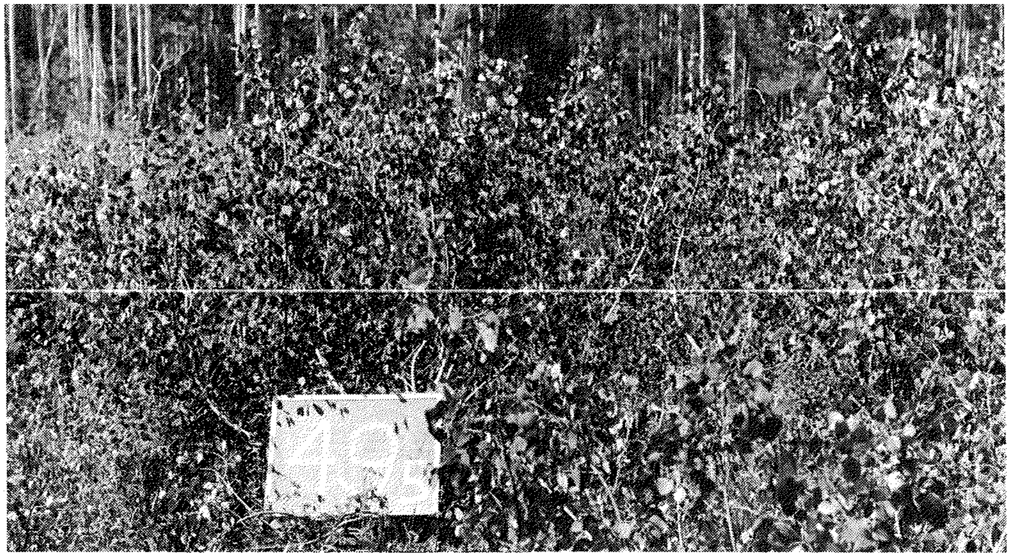

Figure 3. Aspen regeneration after five growing seasons.

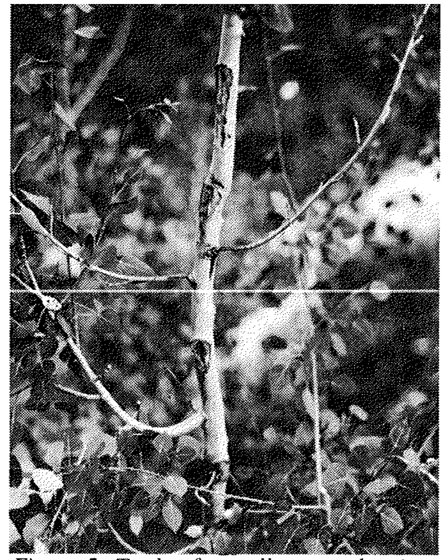

Figure 5. Twelve-foot tall aspen showing stem lesion resulting from branch stripping by snow.

to favor clearcut over uncut areas was evident.

More important, however, was damage caused by snow. Bending to the ground of trees up to 8 inches in d.b.h. was evident along roadsides and clearcut edges after snowmelt. Annual snowfall at a weather station about 10 miles from the study area, and at a similar elevation, averaged 164 ± 44 inches, and annual precipitation 26 ± 4 inches during the seven-year period considered here. Ranger district reports indicate that snow depths of 4 feet or more are common on Stoner Mesa, and the cutting pattern and block size and shape employed in this timber sale have been shown to promote snow deposition in clearcuts in conifer forests in the Rocky Mountains (Troendle and Leaf 1981).

Evidence is strong that snow severely damaged the aspen sprouts. Most of the sprouts with basal decay or discoloration had basal injuries that appeared to be caused mainly by compression from accumulation or settling of snow. Most of these sprouts also exhibited bushy crowns resulting from broken leaders *(fig. 4)*. Many taller, older sprouts, in addition to basal injuries, also showed vertical stem lesions at heights of 6 feet or more, apparently caused by the stripping of branches by snow or ice *(fig. 5)*. This heavy damage to the taller, straight-stemmed sprouts has contributed to the low estimated percentage of crop-tree stocking in the older clearcuts *(table 2)*. Although dominant seven-year-old sprouts averaged more than 8 feet in height, they were still incurring winter-season damage.

The parent stands apparently regenerated without having incurred lasting damage from snow. They did not develop after clearcutting, however, but sprouted after fire, insect attacks, frost damage, senescence, or some other cause which left live or dead standing trees to ameliorate the potential for snow damage.

Declines in numbers of sprouts over time is expected, but enough good, well-distributed individuals must survive to ensure that a silviculturally acceptable stand will develop. Seven thousand sprouts per acre after seven growing seasons would appear to be more than sufficient to provide stocking for a new commercial stand. But the poor condition of most sprouts and the presence of undamaged sprouts in only 35 percent of the sample plots in the oldest clearcut blocks indicate that successful restocking is questionable.

The unsatisfactory conditions of sprout stands seven years after logging suggest that future sales on similar sites might profitably exclude cattle for up to five years, and utilize different shapes and distribution of cutting blocks to ensure a new sawlog stand. ■

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THE AUTHOR—Glenn L. Crouch is principal research wildlife biologist, Rocky Mountain Forest and Range Experiment Station, USDA Forest Service, Fort Collins, Colorado 80526.